

Design and Pressure Analysis of Steel Silo (8000) Tons

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Conforms temporary silos is carried by chain conveyor and bucket elevator to the furnace. One of the furnaces use firewood as a raw material and the other is saw- dust or wood-dust. Corns are dried until the corn moisture from 13.5% to 13.8% and get 13.5 tons of dried corn per hour. Dried corn is stored in dry silos and keeps 24 hours to reduce temperature. After reducing temperature, corn is sent to three storage silos (each silo 8,000 tons) with chain conveyor and bucket elevator.

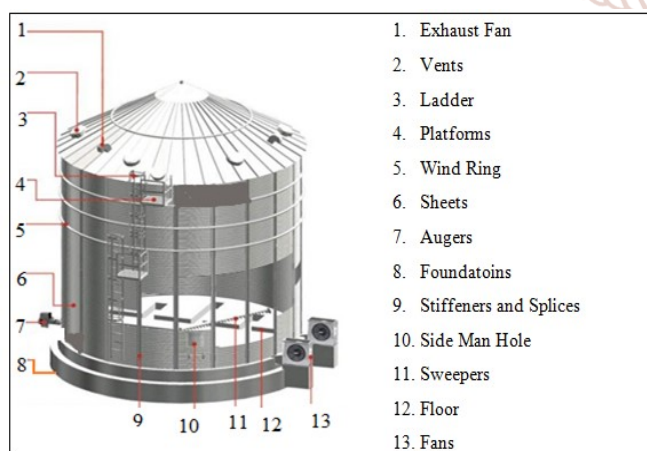


Figure1. Steel Silo Components [6]

Storage corn can be used anytime when needed and extracted from four loads out bins (25 tons per bin) and it is a storage silo and load out bin line of the drying process. And feed mill company uses 100 tons of dried corn per day for making chicken feed. Figure (1) shows the components of a steel silo.

ABSTRACT

This paper describes design and load analysis of steel silo (8000) tons. They are cement storage silo, tower silo, bunker silo, bags silo, bins, sand and salt silo and fabric silo. Tower silos are differentiated as concrete silo and steel silo. Steel silo is analyzed for more economic and safety than other silos. Horizontal pressure, vertical pressure and frictional wall pressure are calculated and got the required thickness is 8.4412 mm. But in CP Live Stock Company, the thickness of silo wall is 6 mm and lowers than the requirement. Therefore, stiffeners are fixed for safety. There are 78 stiffeners and wall thickness is 5.54 mm required. The total vertical stress is 162.66 kN/m² and allowable stress for foundation is 167.43 kN/m². The stress of foundation is greater than total vertical stress. Therefore, design is satisfied. The wind load and wind pressure at different heights are also calculated and based on wind speed of 44 m/s. Wind stress is much less than the wall strength. Therefore, wind stress is neglected and design is satisfied.

KEYWORDS: Steel silo, wall thickness, height, stress, pressure.

I. INTRODUCTION

The term drying refers generally to the removal of moisture from a substance. It is one of the oldest methods, most commonly used and most energy consuming unit operation in the process industry. The yellow corn drying process consists of intake receiving and cleaning line, dryer and temporary dry silo line and storage silo and load out bin line.

The exhaust fan is placed at the top of the silo. This fan is to remove the warm air from the silo and used in special aeration systems where the silos are placed in a humidity region. Vents are available in both of the elbows and round mushroom styles to help ensure free air movement throughout the bin. There are 18 vents on the roof. Ladder is assembled from the floor to roof section. It provides easy access to the man hole placed at the roof. There are 100 steps from bottom to roof. Resting platform is placed under the man hole for safety visual check inside the silo. Roof compression rings provide additional support and another level of safety for those working on top of the bin.

Side wall body sheets are 8 through 20 gauge commercial grade G-90 galvanized steel with a minimum tensile strength of up to 65,000 psi (448 MPa) and minimum yield strength of up to 50,000 psi (345 MPa) to protect grain and provide maximum strength at all levels. On taller bins, two sidewall panels are laminated together for greater strength. Side wall stiffener are among the strongest available to help manage the stress and strain of weather, grain, cable and roof mount equipment. Sidewalls are assembled using high-strength Grade 8.2 bin seal bolts with special JS-1000 coating to provide superior weather-resistance. Optional polypropylene-encapsulated head bolts provide enhanced corrosion resistance.

There are seven holes for corn outlet. But, only the middle hole is used for safety. If the side holes are used, unexpected losses will occur. The side holes can be used, when there is no corn in the middle hole. When there is no flow of corn in all the seven holes, using sweep auger to flow the corn.

Sweep auger must be keeping straight to the side man hole for manual operating. Grease must be changed, after running 50 hours. Foundation of the silo is of 152 concrete piles to support it.

Large roof manhole has an ob-round shape and rotating latch for easy entry and exit. Side manhole offers simple yet safe access, with a one-piece outer door and four interlocking inner panels that open in sequence from top to bottom with a lift of a latch. Bin anchor system creates a strong weather-tight connection to the foundation protecting investment from wind up to 90mph. It allows for single pass sweeping and eliminates need for entry during the processes. The bottom tire side wall is reinforced to enter the bin and prevent moisture penetration. The two centrifugal aeration fans are to reduce the grain's temperature in the silo which operates with 15 hp and 1,450 rpm. These cables are to determine the temperature of the storage corn. In cable A1, there are 14 sensor points. In cable A2 to A5, 13 sensor points and in A6 to A14, there are 12 sensor points. The temperature of the storage corn is measured with measurement tool "StorMax", twice a week between 2-4 PM. To conserve the quality of products over long-term storage, degradation processes must be slowed down or even stopped. Degradation of grains during storage depends principally on a combination of two factors:

- Temperature and Moisture
- Oxygen Content

During storage and other phases of the post-harvest system, the combined effects of these two factors can sometimes cause several losses. Temperature and moisture are determining factors in accelerating or delaying the complex phenomena of the biochemical transformation (especially the "breathing" of the grain) that are at the origin of grain degradation. Furthermore, they have a direct influence on the speed of development of insects and micro-organisms (moulds, yeast and bacteria), and on the premature and unseasonal germination of grain. It is easy to observe that the higher the temperature, the lower must be the moisture of the grain in order to ensure good conservation of the products. In view of their influence on the speed of development of these degradation phenomena, the temperature and moisture content of the grain condition the maximal duration of storage [6].

II. Design and Wind Load Analysis of Steel Silo

In this standard, Janssen's Theory has been used for the assessment of bin height. The theory has been suitably modified wherever necessary and with this the structural adequacy and safety are ensured. In this paper, design specifications are as follow.

A. Specification Data of Steel Silo

To design steel silo must be known diameter, height of roof section, wall thickness and material properties.

TABLE I. DESIGN PARAMETER OF STEEL SILO

Design parameter	symbol	value	Unit
diameter of steel silo	D	28.3	m
height of roof section	l	6.25	m
wall thickness	t	6	mm
No. of stiffeners		78	mm
Density of corn	ρ	720	Kg/m ³

Table I shows the parameters considered for design of steel silo.

B. Calculation of Capacity in Silo

The minimum thickness or maximum allowable working pressure of cylindrical shells can be the greater thickness or lesser pressure. When the thickness does not exceed one-half of the inside radius, or P does not exceed $0.385\sigma_{all}\eta$, the following formulas can be applied [5].

$$\text{Volume of Circular Section} = \frac{\pi}{4} \times d^2 \times l \quad (1)$$

$$\text{Capacity in Circular Section} = \rho \times V \quad (2)$$

$$\text{Volume of Roof Section} = \frac{1}{3} \pi \times r^2 \times h \quad (3)$$

$$\text{Capacity in Roof Section} = \rho \times V \quad (4)$$

C. Maximum Pressures

The maximum values of the horizontal pressures on the wall (P_h), the vertical pressure on the horizontal cross section of the stored material (P_v) and the vertical load transferred to the wall per unit area due to friction (P_w) shall be calculated as given in Table II.

TABLE II GRANULAR MATERIAL

Name of Pressure	During Filling	During Emptying
Frictional Wall Pressure	γR	$\gamma_e R$
Horizontal Pressure	$\frac{\gamma \times R}{\mu_f}$	$\frac{\gamma \times R}{\mu_e}$
Vertical Pressure	$\frac{\gamma \times R}{\mu_f \lambda_f}$	$\frac{\gamma \times R}{\mu_e \lambda_e}$

D. Variation of Pressure along Different Depths

The variation of P_w , P_h and P_v along the depth of the bin may be obtained from the expression given below.

$$P_i(Z) = (P_i)_{\max} \left[1 - e^{-\frac{Z}{Z_0}} \right] \quad (5)$$

Where P stands for pressure and suffix is stands for w , h or v corresponding to the pressure P_w , P_h or P_v respectively and assumes the values given below:

During Filling,

$$Z_{of} = \frac{R}{\mu_f \lambda_f} \quad (6)$$

During Emptying,

$$Z_{oe} = \frac{R}{\mu_e \lambda_e} \quad (7)$$

where, Z_0 =mean height, m

Z =height of corn stored, m

In general, it is not necessary to evaluate the stress resultant in the silo wall under wind loading, except for the purposes of evaluating the requirements for holding down details. The reason is that the buckling failure criteria for this load case have been developed to take into account the rather complex mixture of circumferential and vertical stresses that develop in silo walls under wind, so the wall stress analysis is eliminated.

E. Janssen's Theory

Most of the weight of the material stored in the bin is supported by friction between the material and the vertical wall. Weight transferred to the hopper bottom is very less. (Hence Rankine or Coulomb's lateral pressure theory cannot be applied.) The vertical wall of the bin is subjected to vertical force and horizontal pressure [4].

$$P_h = \frac{W \times R}{\mu} \times \left(1 - e^{-\frac{z}{Z_0}} \right) \quad (8)$$

$$Z_0 = \frac{R}{\lambda \times \mu} \quad (9)$$

where, z = height of corn stored, m

Z_0 = mean height, m

$R = \frac{(\text{area}) A}{(\text{parameter}) U}$ relative mean radius, m

P_v = vertical pressure, N/m²

P_h = horizontal pressure, N/m²

W = unit weight of stored material (Table A1)

A = cross section area of material stored, m²

Φ = angle of internal friction of stored material

μ = coefficient of friction of grain, ($\mu = \tan \phi$)

λ = pressure ratio, $\frac{P_h}{P_v}$

The hoop tension on the wall is

$$H_t = P_{h(\max)} \times \frac{D}{2} \quad (10)$$

where, D = diameter of silo, m

H_t = Hoop Tension, N/m

To find the thickness of the wall, the following equation must be taken.

$$\text{Stress}_{\text{Max, Com}} = \frac{H_t}{t} + \frac{\text{Total vertical load per mm}}{t} \quad (11)$$

Check on Wall Pressure,

$$\sigma_h = \frac{P_h \times D}{2t} \quad (12)$$

$$\sigma_l = \frac{P_v \times D}{4t} \quad (13)$$

where, σ_h = hoop stress, MPa

σ_l = longitudinal stress, MPa

t = thickness of wall, mm

F. Calculation of Foundation

For Base of Silo;

$$\text{Total Vertical Stress} = \frac{\text{Total Vertical Load}}{\text{Area of Silo}} \quad (14)$$

$$\text{Stress of Base} = \frac{\text{Weight of Base}}{\text{Area of Base}} \quad (15)$$

For Piles (Foundation);

$$\text{Stress of Pile} = \frac{\text{Weight of Pile}}{\text{Area of Pile}} \quad (16)$$

G. Analysis of Wind Load

Buildings are subject to horizontal loads due to wind pressure acting on the buildings. Wind load is calculated as per IS 875(Part III) -1987. The horizontal wind pressure act on vertical external walls and exposed area of the buildings. Some of the pressure acting on exposed surfaces of structural buildings is subject to horizontal loads due to wind pressure acting on the buildings. Wind load is calculated as IS 875(Part III)-1987. The horizontal wind pressures act on vertical external walls and exposed area of the buildings. Some of the pressure acting on exposed surfaces of structural walls and columns is directly resisted by bending of these members [4].

Design wind speed is given by the equation,

$$V_z = V_b \times K_1 \times K_2 \times K_3 \quad (17)$$

Where, V_z = Design wind velocity, m/s

V_b = Basic wind speed, m/s

K_1 = Risk Coefficient, (Table A3)

K_2 = Terrain, height and structure size factor

K_3 = Topography factor

III. Results and Discussion

In this paper, the results of pressure at the different height are computed by theoretical. The resulted data for thickness of wall sheet and number of stiffeners are obtained. The wind load and wind pressure at different heights are also calculated and based on wind speed of 44 m/s.

TABLE III RESULT DATA FOR PRESSURES AT THE DIFFERENT HEIGHT

	h = 9 m	h = 18 m	h = 26 m	h = 27 m
Z_{of}	32.258	32.258	32.258	32.258
Z_{oe}	20.482	20.482	20.482	20.482
Z / Z_{of}	0.279	0.558	0.801	0.837
Z / Z_{oe}	0.439	0.879	1.262	1.318
P_w (kN/m ²)	16.913	27.837	34.125	34.859
P_h (kN/m ²)	58.220	95.823	117.469	119.996
P_v (kN/m ²)	62.822	110.36	142.224	146.32

Table III shows result data of pressure at the different height. The maximum value of the horizontal pressure, vertical pressure and frictional wall pressures are occurred at 27 m height.

TABLE IV RESULT DATA FOR THICKNESS OF WALL SHEET

Number of Stiffener per Sheet	Weight of Stiffener per mm	Thickness of Wall Sheet (mm)
1	59.865	8.141
2	239.796	7.238
3	538.796	5.541

Table IV shows result data of thickness of wall sheet. The thickness of wall sheets is 6mm used in C.P Live Stock Company and lowers than the calculation result 8.141 mm. Therefore, stiffeners are required for satisfied design.

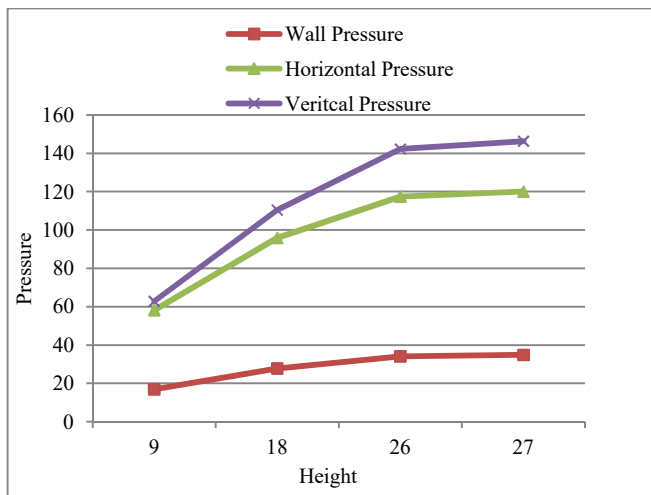


Figure2. Comparison of Pressure at Different Height

Figure 2 represents comparison of pressure at different height.

TABLE V RESULT DATA FOR FOUNDATION

	Values	Unit
Total Vertical Stress	162.7	kN/m ²
Stress of Base	24.7	kN/m ²
Stress of Pile	149.7	kN/m ²
Total Strength of Base	167.4	kN/m ²

Table V shows result data of foundation. Total strength of base is greater than total vertical stress. Therefore, design is safe.

TABLE VI RESULT DATA FOR WIND PRESSURE AND WIND LOAD

Height	Wind Pressure	Wind Load
10	1.3	364.8
20	1.5	418.7
30	1.6	459.6

Table VI shows result data of wind pressure and wind load at the different height. The maximum values of the wind pressure and wind load are occurred at 30 m height.

IV. Conclusions

A complete design of steel silo (8000) tons has been presented in this paper. In this paper analysis of the steel silo (8,000 tons) for horizontal pressure, vertical pressure and

wall pressure at different depths, during filling and emptying has been calculated by using Janssen's theory. The maximum value of the horizontal pressure, vertical pressure and frictional wall pressures are 119.996 kN/m², 146.32 kN/m² and 34.859 kN/m² at 27 m height. For 8,000 tons, there is only 25.85 metre and pressures are 117.4697 kN/m², 142.224 kN/m² and 34.125 kN/m². At horizontal pressure 117.4697 kN/m², hoop tension is calculated for thickness of wall sheets. The thickness of wall sheets is 6mm used in C.P Live Stock Company and lowers than the calculation result 8.4412 mm. Therefore, stiffeners are required for satisfied design.

There are three stiffeners per sheet from calculation and thickness is decreased to 5.5413 mm. Also the wall strength is checked by pressure vessel equation and lowers than the yield stress. Therefore, design is satisfied. And then, the foundation is calculated and the stress of 149.49 kN/m² is resisted on each pile. The total vertical stress is lower than the strength of foundation 152 piles. As a result, design is safe. Then, the wind load and wind pressure are also calculated. Wind stress exerted on wall is very small. Therefore, wind stress can be neglected and design is satisfied.

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